HOW TO DRAW A STRAIGHT LINE[1]

IV.

I NOW come to the second of the parallel motions I said I would show you. If I take a kite and pivot the blunt end to the fixed base and make the sharp end move up and down in a straight line, passing through the fixed pivot, the short links will rotate about the fixed pivot with equal velocities in opposite directions; and, conversely, if the links rotate with equal velocity in opposite directions, the path of the sharp end will be a straight line, and the same will hold good if instead of the short links being pivoted to the same point they are pivoted to different ones.

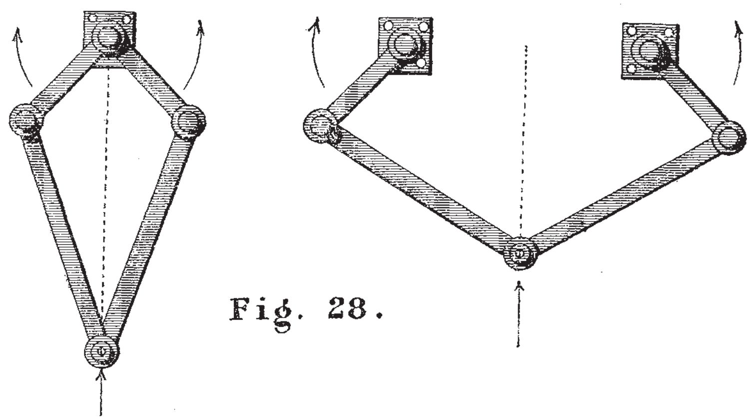

Fig. 28.

To find a linkwork which should make two links rotate with equal velocities in opposite directions was one of the first problems I set myself to solve. There was no difficulty in making two links rotate with equal velocities in the same direction—the ordinary parallelogrammatic linkwork employed in locomotive engines, composed of the engine, the two cranks, and the connecting rod, furnished that; and there was none in making two links rotate in opposite directions with *varying* velocity; the contraparallelogram gave that; but the required linkwork had to be discovered. After some trouble I succeeded in obtaining it by a combination of a large and small contra-parallelogram put together just as the two kites were in the linkage of Fig. 18. One contra-parallelogram is made twice as large as the other, and the long links of each are twice as long as the short.

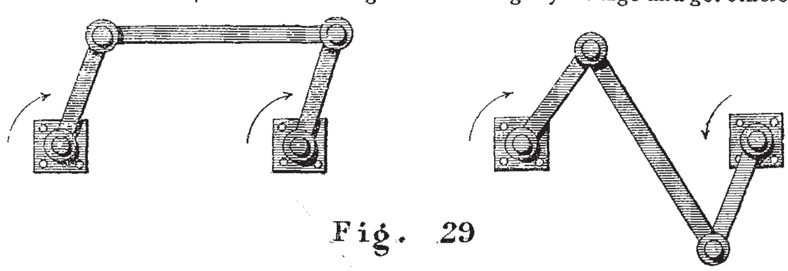

Fig. 29

The linkworks in Figs. 30 and 31 will, by considering the thin line drawn through the fixed pivots in each as a link, be seen to be formed by fixing different links of the same six-link linkage composed of two contra-parallelograms as just stated. The pointed links rotate with equal velocity in opposite directions, and thus, as shown in Fig. 28, at once give parallel motions. They can of course, however, be usefully employed for the mere purpose of reversing angular velocity.

An extension of the linkage employed in these two last figures gives us an apparatus of considerable interest. If I take another linkage contra-parallelogram of half the size of the smaller one and fit it to the smaller exactly as I fitted the smaller to the larger, I get the eight-linkage of Fig. 32. It has, you see, four pointed links radiating from a centre at equal angles; if I open out the two extreme ones to any desired angle, you will see that the two intermediate ones will exactly *trisect the angle*. Thus the power we have had to call into operation in order to effect Euclid's first postulate—linkages—enables us to solve a problem which has no "geometrical" solution. I could of course go on extending my linkage and get others which would divide an angle into any number of equal parts. It is obvious that these same linkages can also be employed as linkworks for doubling, trebling, &c., angular velocity.

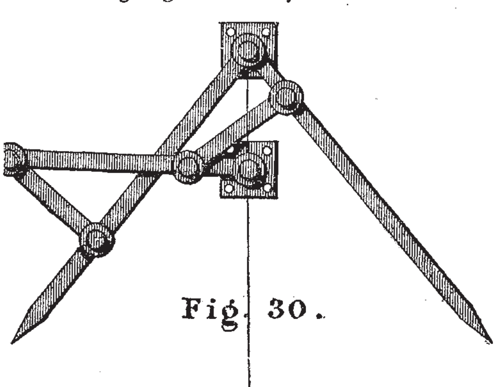

Fig. 30.

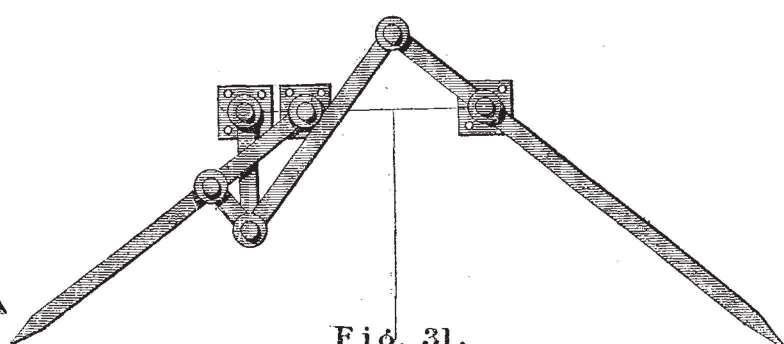

Fig. 31.

Another form of "Isoklinostat," for so the apparatus is termed by Prof. Sylvester, was discovered by him. The construction is apparent from Fig. 33. It has the great advantage of being composed of links having only two pivot distances bearing any proportion to each other, but it has a larger number of links than the other, and as the opening out of the links is limited, it cannot be employed for multiplying angular motion.

Subsequently to the publication of the paper which contained an account of these linkworks of mine of which I have been speaking, I pointed out in a paper read before the Royal Society, that the parallel motions given

[1] Lecture at South Kensington in connection with the Loan Collection of Scientific Apparatus, by A. B. Kempe, B.A. Concluded from p. 127.

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there were, as well as those of M. Peaucellier and Mr. Hart, all particular cases of linkworks of a very general character, all of which depended on the employment of a linkage composed of two similar figures. I have not sufficient time, and I think the subject would not be sufficiently inviting on account of its mathematical character, to dwell on it here, so I will leave those in whom an interest in the question has been excited to consider the original paper.

At this point the problem of the production of straight-line motion now stands, and I think you will be of opinion that we hardly, for practical purposes, want to go much farther into the theoretical part of the question. The results that have been obtained must now be left to the mechanician to be dealt with, if they are of any practical value. I have, as far as what I have undertaken to bring before you to-day is concerned, come to the end of my tether. I have shown you that we *can* describe a straight line, and *how* we can, and the consideration of the problem has led us to investigate some important pieces of apparatus.

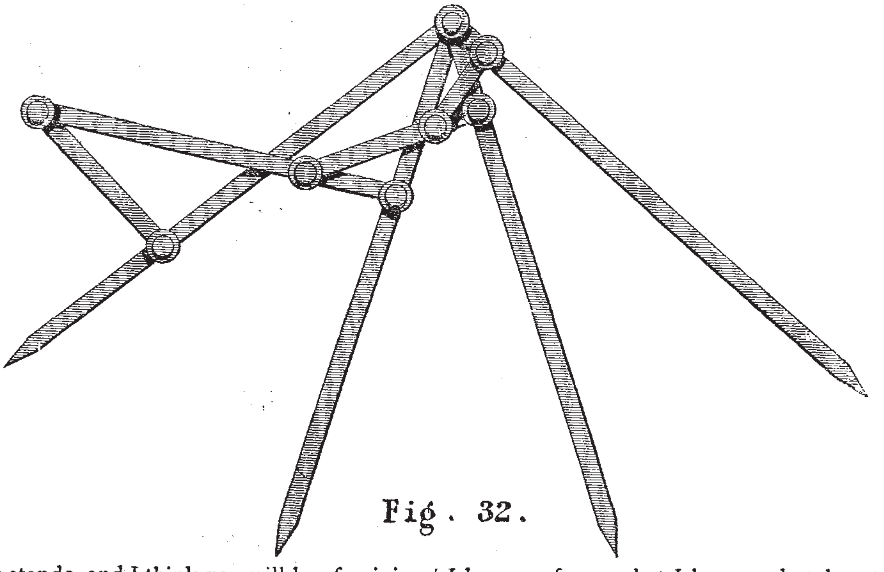

Fig. 32.

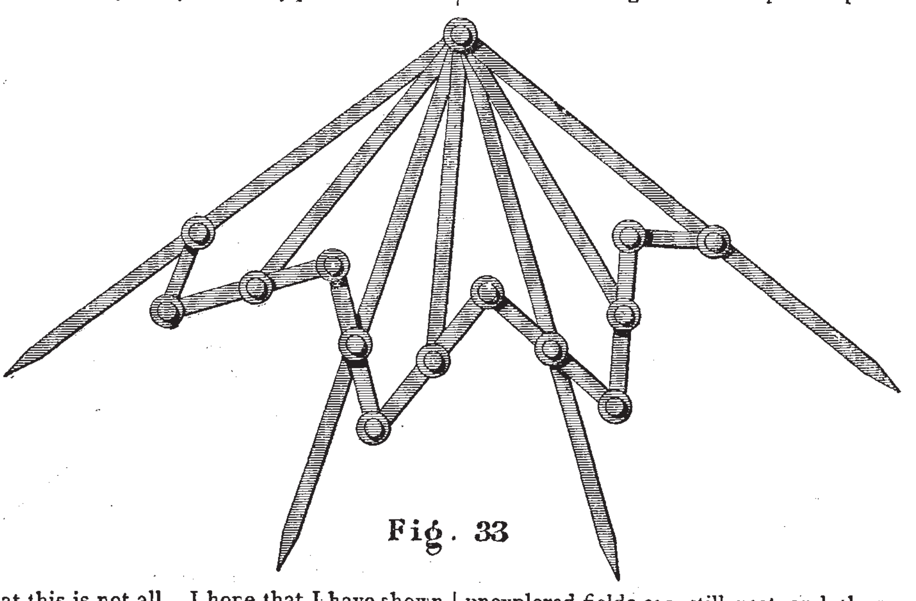

Fig. 33

But I hope that this is not all. I hope that I have shown you (and your attention makes that hope a belief) that this new field of investigation is one possessing great interest and importance. Mathematicians have no doubt done much more than I have been able to show you to day, but the unexplored fields are still vast, and the earnest investigator can hardly fail to make new discoveries. I hope therefore that you whose duty it is to extend the domain of science will not let the subject drop with the close of my lecture.

BIOLOGICAL NOTES

THE TICHORHINE RHINOCEROS.—A number of the *Memoirs* of the Imperial Academy of Sciences of St. Petersburg just issued contains an elaborate article on the Tichorhine Rhinoceroses by the veteran naturalist, Dr. J. F. Brandt. Dr. Brandt treats of two extinct species under this category, which he calls *R. antiquitatis* (i.e., *R. tichorhinus*, auctt.) and *R. merkii*. With the latter he proposes to unite *R. etruscus* of Falconer. Remarks are added upon *R. leptorhinus* of Cuvier and other allied species. When we consider the number of valuable con-